

## SVLBI CONTINUED FROM PAGE 9

Installation of C-band receivers on the DSN 70-m antennas was considered too expensive.

A key new element for automating SVLBI co-observing sessions was the Equipment Activities Controller (EAC). Originally developed for automating radio astronomy observations with DSN radio telescopes, the EAC functions as the interface between the PCFS, which controls the station's VLBI recorder, and DAT, the Radio Astronomy Controller (RAC), which controls the radio astronomy receiver configuration and calibration, and DSN standard subsystem controllers such as the Antenna Pointing Assembly (APA). The EAC provides the main interface for the DSN operators, through which they direct the operations, which include observing session initiation, station configuration, configuration and performance tests, and antenna pointing during the observations.

The RACs also had to be standardized across the Network, and new software was written to provide an R&D equipment control service to such clients as the EAC.

Significant efforts went into streamlining the SVLBI co-observing logistics, such as calibration procedures, tapes shipment, log and clock correction files delivery to the correlator, etc. The Goldstone Complex reported readiness to support SVLBI co-observing in November 1997. In January of this year, the Madrid Complex also reported itself ready. Problems unique to the Canberra Complex have delayed readiness, but

these are expected to be solved soon. A formal release and transfer of the software to DSN Operations is scheduled for the Ides of March.

In addition to the standard configuration, a Canadian-built S-2 recorder has been installed at the Canberra Complex by the CSIRO Australia Telescope national facility (ATNF), an Australian organization that participates in radio astronomy observations at CDSCC.

### First Space VLBI Results

The first fringes of the interferometer between the HALCA space radio telescope and the ground-based 64-m radio telescope in Usuda, Japan, were detected in May 1997. The DSN's 70-m Tidbinbilla radio telescope was the first non-Japanese radio telescope with which fringes were detected in an experiment held a few weeks later. The first observations involving Tidbinbilla were done at L-band, recording in S-2 format. The data were processed at the S-2 correlator in Canada. Figure 1 shows these first fringes between Tidbinbilla and HALCA (courtesy of Dominion Radio Observatory, Canada).

During June–July 1997, a series of observations with the VLA and VLBA obtained fringes at L-band on multiple Earth-space baselines. A few images of radio sources were produced. These images revealed unresolved structure in radio sources observed with baselines of more than two Earth diameters. An example of such an image from the VSOP observation with VLBA is given

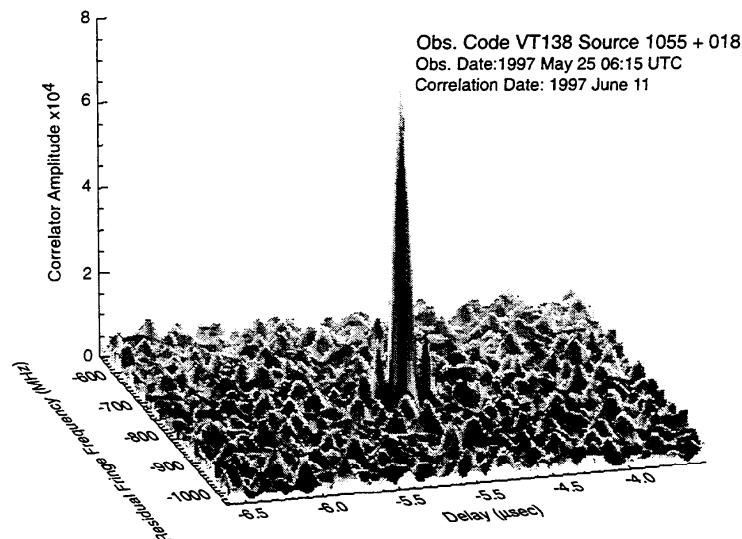


FIGURE 1. FIRST FRINGES OBTAINED ON MAY 26, 1997, BETWEEN THE HALCA SPACE TELESCOPE AND THE TIDBINBILLA 70-M TELESCOPE

## SVLBI CONTINUED FROM PAGE 10


in Figure 2 (courtesy of NRAO). The image of this distant quasar, 1156+295, made from ground telescopes only, is shown on the left. On the right is another image of the quasar, but with the radio signals from VSOP satellite added. The material blown out from the quasar can be seen more clearly in this second picture. This unprecedented, angular resolution at the observing wavelength 18 cm (L-band) allows radio astronomers to probe closer to the center of the quasar, in order to understand the nature of these objects.

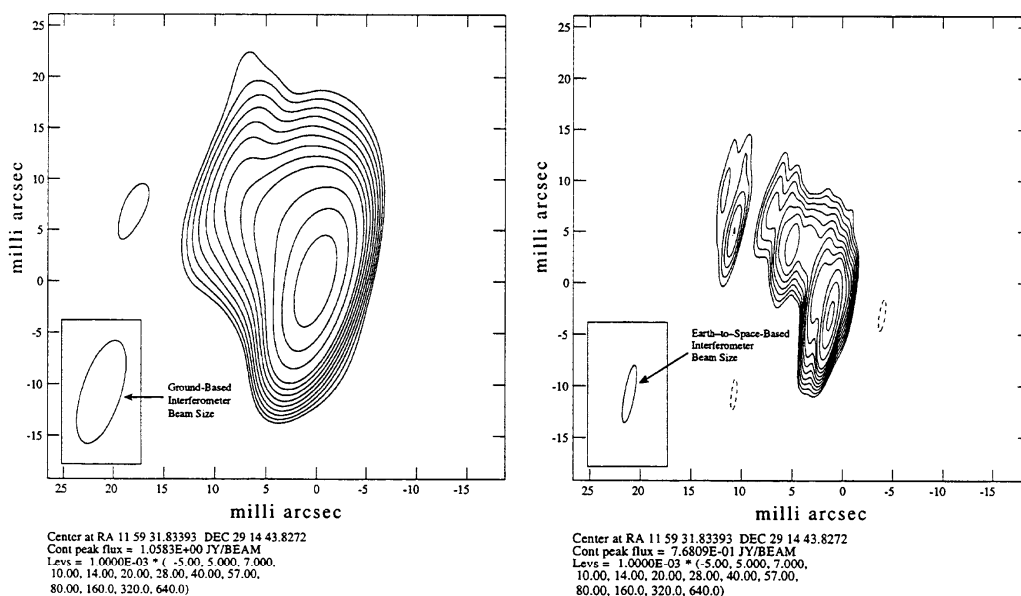
After the first successful observation with S-2 recording in Tidbinbilla, the Goldstone and Tidbinbilla radio telescopes have participated in several observing sessions using MKIV recording. The Goldstone 70-m radio telescope was the first MKIV radio telescope with which the Earth-to-space fringes were detected.

### Conclusions

Space VLBI co-observing, one of the most important space radio astronomy projects in the DSN in recent years, is entering its operation phase. The first dedicated Space VLBI mission — HALCA — has begun to produce important radio astronomical results, and the DSN 70-m telescopes are playing a significant role in this exciting undertaking.

The DSN 70-m telescopes will play an important role in future Space VLBI missions. The next scheduled space telescope is the Russian RadioAstron. It will have 50 percent more collecting area than HALCA and will be equipped with dual polarization receivers. The DSN K-band receivers are dual polarizations, and a redundant, down-conversion chain will allow two polarizations to be recorded, simultaneously. Converting the DSN 70-m L-band systems to dual polarization is being considered. A Japanese follow-on mission tentatively being called VSOP2, with a 15–20 m telescope operating at 22 GHz and possibly higher frequencies, is also being discussed.

An advanced U.S. space VLBI mission called ARISE is being planned. This will also involve a larger antenna, perhaps 25-m in diameter, and operate at higher frequencies, including 43 GHz and possibly 86 GHz. DSS-13 has been operating as a radio telescope in the 40–50 GHz band for several years, and a receiver capable of 86 GHz observations is nearing completion. There are few ground-based radio telescopes capable of observation at 86 GHz. The DSN 34-m beam waveguide guide (BWG) subnet, suitably equipped, could be a key asset to such a project. 



**FIGURE 2. IMAGES OF QUASAR 1156+295 OBTAINED FROM FRINGES RECORDED ON JUNE 24, 1997.**  
THE LEFT IMAGE WAS OBTAINED USING THE GROUND-BASED TELESCOPES ALONE.  
THE RIGHT IMAGES INCLUDE THE FRINGES OBTAINED WITH HALCA

## ARTSN CONTINUED FROM PAGE 8

precision level. Specific validation checks included:

- Trajectory and transition matrix integration
  - Observable and partial generation
  - Batch filtering
  - State and covariance mapping
- (2) After this validation, a 'real world' test was performed, where ARTSN was fed inputs from the Mars Pathfinder navigation team to produce current state and epoch state solutions over a 76-day data arc. The ARTSN solutions were used to make encounter estimates. In both modes, the ARTSN estimate agreed with that generated by the Pathfinder navigation team to within less than half of the Pathfinder estimate uncertainty.
  - (3) A presentation was given to the navigation section in July 1997. The results of Case 2 were reported, and a demonstration was performed using an unedited recording of a DSN broadcast of the final two weeks of the Mars Pathfinder cruise. This time span included the final maneuver, TCM-4, and a patch of data corrupted by the improper application of a leap second correction. As the data were processed, the solution evolved, which accounted for the maneuver and rejection of most of the corrupted data.
  - (4) The Mars Global Surveyor (MGS) navigation team demonstrated real-time navigation using ARTSN during the Mars Orbit Insertion (MOI) on September 11, 1997, and during the aerobraking phase of the mission to date. ARTSN read radio metric Doppler data in real time and computed measurements based on an ARTSN-generated nominal trajectory. Streams of observable and residual values


were piped to several displays in real-time, both to the public (Figure 2) and the navigation analysts themselves.

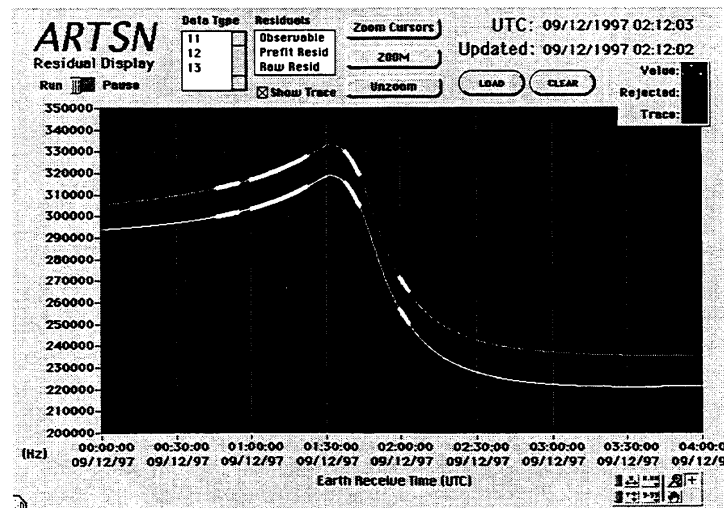
- (5) The MGS navigation team continued to use the ARTSN displays to monitor aerobraking-related events, such as periapsis-lowering maneuvers, and tracking before and after each periapsis pass. The line-of-sight Doppler shifts during the maneuvers were reported back to the project as a 'quick-look' assessment of the event, and the effective Doppler shift from each aerobraking pass was also monitored as tracking resumed after each pass.

### FY98 Plans

The vision for ARTSN for the next year includes an expansion of its capabilities and more demonstrations of its utility and workforce savings (pending the resolution of funding issues). There are sets of rapid turnaround applications where a real-time capability can make a strong impact, including additional aerobraking monitoring for MGS, launch support, general maneuver monitoring, and approach navigation. Second, there are scenarios where an autonomous or nearly autonomous presence would be of benefit, such as spacecraft trajectory predictions for ground tracking stations or autonomous orbit determination for a spacecraft in a long, quiet, cruise phase.

### Reference

Masters, W. C., and V. M., Pollmeier, "Development of a Prototype Real-Time Automated Filter for Operational Deep Space Navigation," *Third International Conference on Space Mission Operations and Ground Data Systems*, Goddard Space Flight Center, Greenbelt, MD, 14-18, November 1994. 



**Top Trace** - Predicted 1-way Doppler Obs. for DSS 15 for a nominal MOI

**Bottom Trace** - Predictions for DSS 45

**Heavy Traces** - Processed Doppler Obs.

FIGURE 2. ARTSN DISPLAY OF DOPPLER OBSERVABLES SHOWN ON THE JPL/MGS HOME PAGE DURING MOI